CHAPTER 5 - WATER RESOURCES IMPACT ISSUES

INTRODUCTION

The production of coal bed methane (CBM) has the potential to impact water resources in a variety of ways. Drawdown of coal seam aquifers is an unavoidable impact because the de-pressurization of coal seams is inherent to the process of CBM production. Once brought to the surface during production operations, produced water is essentially a waste bi-product that must be disposed of. Options for disposal include discharge to land or surface water bodies, re-injection, or one of many beneficial use options (e.g., stock watering, controlled irrigation, dust control, storage impoundments, etc.).

The combination of potentially substantial water volumes combined with relatively poor to moderate water quality characteristics emphasizes the needs to closely evaluate and monitor CBM development and production. Depending on the area, groundwater and/or surface waters may vary in potential vulnerability. To fully understand these potential vulnerabilities and impacts, analysis of both groundwater and surface water is required.

GROUNDWATER DRAWDOWN FROM CBM DEVELOPMENT

Groundwater drawdown from CBM production has been documented inside and adjacent to existing production in Montana. CBM production in the PRB requires drawdown of coal aquifers within the producing field in order to liberate methane. Water wells adjacent to but outside of a producing CBM field may also be adversely impacted. Drawdown can be documented by way of dedicated monitoring wells or by gauging private water wells. In Montana's CX Ranch CBM field, the MBMG has installed monitoring wells designed to track drawdown due to the coal mines in the area as well as CBM development.

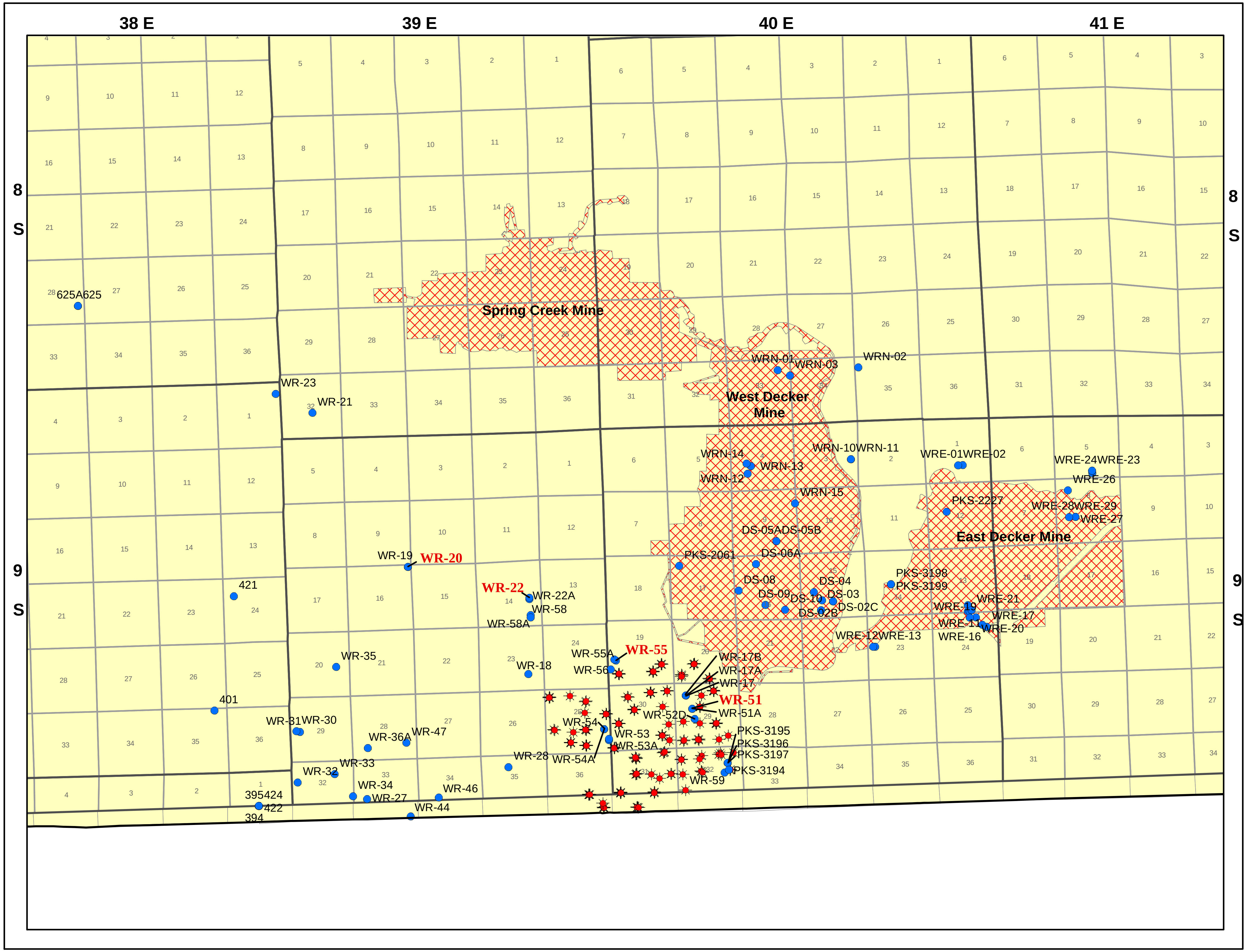
Exhibit 25 is a location map of monitoring wells, CBM wells, and coal mines near Decker, Montana. This exhibit show the spatial relationship between monitoring stations and both coal mine development and active CBM production at the CX Ranch field. Both water level and water quality data have been collected at the monitoring wells identified, although some are currently inoperative. Some of these monitoring wells are periodically checked and sampled. Monitoring data for these wells were obtained from the Montana Bureau of Mines and Geology.

Hydrographs of 13 separate monitoring wells in the area of the CX Ranch field are presented in Appendix D. Monitoring well WR-51 is located within the boundaries of active commercial CBM production. These hydrographs document drawdown impacts from CBM production at the CX Ranch field at distances of approximately 0.0 to 4.2 miles away from active production. The recorded drawdowns occurred within two years of the start of CBM production. Some monitoring wells in or near CBM operations (e.g., WR-51, WR-53 and WR-55) indicate that sudden drawdowns can occur as a result of CBM production coupled with coal mine withdraws. Other monitoring wells located further from CBM operations at the CX Ranch field still showed noticeable reductions without signs of stabilizing considering currently available data and information. Some monitoring wells showed no evidence of drawdown from CBM activity.

When evaluating these hydrographs, it is important to recognize that CBM operations may be ongoing for 15 to 20 years. The combination of extraction rates and duration has escalating effects that may cause groundwater drawdown impacts for several miles from active CBM producing operations. Predicting the actual outer distance of drawdown impacts within coal seams is difficult across the PRB in Montana because the basin has only a fraction of the development that may occur. Furthermore, the PRB in Montana is a geologically complex area with relatively sparse information regarding hydrogeology.

Exhibit 26 summarizes the water level data of 14 monitoring wells in or adjacent to the CX field for which coal aquifer data is available. Those wells closest to the center of CBM development tend to show drawdown at the earliest date, however there are exceptions. The degree of draw-down recorded appears to be due to water production from the nearly 200 CBM wells now on-line at the CX field as summarized above; production began with the drilling of the first CBM wells in March 1998 and first pumping in December 1998 (Williams 2001).

Exhibit 25: Location Map of Monitoring Wells, CBM Wells, and Coal Mines near Decker, Montana

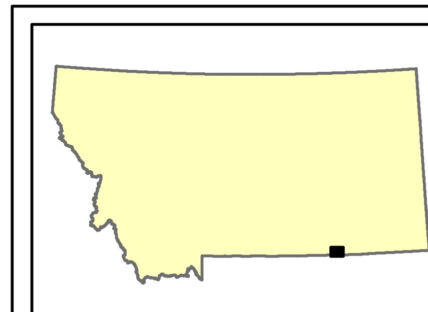


Legend

- Public Land Survey System
- Coal Mines

WELLS

- Producing CBM Wells
- Monitor Wells



Location Map

Date Prepared: April 2, 2001

Prepared by: J. Patton

Project Mgr.: D. Arthur

N W E S

1:100,000

2 1 0 2 Miles

2,000 1,000 0 2,000 4,000 Meters

DATA SOURCES

Public Land Survey System: 1:100,000 scale, PLSS, Montana State Library/NRIS, Helena, Montana, supplemented by 1:100,000 scale USGS PLSS Digital Line Graphs.

Mines: Montana Bureau of Mines & Geology.

Water Data: Montana Bureau of Mines & Geology Water Well Database.

CBM Well Data: Montana Board of Oil and Gas Conservation Online Database.

RMP Boundary: BLM Miles City Field Office.

EXHIBIT 26 - SUMMARY OF WATER LEVEL DATA FROM CX FIELD MONITORING WELLS

Statistics on the13 hydrographs in the vicinity of CX Ranch CBM Field

MONITORING WELL	DISTANCE FROM NEAREST CBM WELL	DATE OF ONSET OF DRAW-DOWN	TIME FOR DRAW-DOWN TO REACH WELL	MAXIMUM DRAW-DOWN
WR-17	0.0 miles	10/1999	11 months	21 feet
WR-51	0.0 miles	1/1999	1 month	111 feet
WR-53	0.0 miles	10/1999	11 months	74 feet
WR-53A	0.0 miles	11/2000	24 months	2.0 feet
WR-54	0.0 miles	10/1999	11 months	38 feet
WR-55	0.2 miles	11/1999	12 months	51 feet
WR-28	0.92 miles	None	-	0.0 feet
WR-22	1.8 miles	3/2000	16 months	10 feet
DS-05A	2.40 miles	None	-	0.0 feet
WR-27	3.12 miles	None	-	0.0 feet
WR-19	3.68 miles	None	-	0.0 feet
WR-20	3.68 miles	None	-	0.0 feet
WRE-10	4.20 miles	None	-	0.0 feet

Monitoring well WR-51, screened in the D-2 coal, is in the midst of CBM wells and showed the first signs of drawdown immediately after onset of pumping in January 1999. WR-51 currently shows 111 feet of drawdown but is probably not at equilibrium and is likely to show more drawdown in the future.

Monitoring well WR-55, screened in the D-2 coal, which is approximately 0.2 miles beyond current CBM development, showed drawdown in November 1999; this well currently shows a drawdown of 51 feet, but also is not at equilibrium and drawdown may increase with continued CBM production.

The radius of impact to area water levels has moved out at least 1.8 miles to well WR-22, screened in the D-1 and D-2 coals. The WR-22 first saw drawdown in March 2000 but shows only approximately 10 feet of drawdown.

It is unclear what the limit of drawdown will be as the field continues to produce CBM. It may be that as pumping rates drop in the CX Ranch Field, the drawdown radius of impact may cease spreading and may stabilize.

The CX Ranch is still being developed and producing wells are being added. Full extent of CBM development and full extent of offsite aquifer drawdown cannot be estimated at the present time. It is possible that if further development doesn't take place, the WR-22 well may not be drawn down beyond its present point. It is also possible that if more CBM wells are drilled, then WR-22 may be surrounded by CBM wells and drawdown will likely increase more rapidly.

Groundwater drawdown can result in wide-ranging methane migration phenomena under adjacent leases including methane liberation into in nearby water wells, coal fires, etc. have been observed in other coal basins. The PRB is sufficiently different from the San Juan Basin (SJB); however, it may not support methane migration away from aquifer drawdown. Methane liberation into non-produced water wells has been demonstrated at CX Ranch, the extent of the phenomenon is unknown at the present time.

The San Juan Basin (SJB) has experienced gas seeps and coal fires that appear to be increasing in number in concert with increasing CBM production (BLM, 2000b). It is hypothesized that nearby CBM production has intensified seep activity. Specifically, lowering of the water table in the monocline by downdip dewatering of coal beds is postulated to allow CBM to desorb from coal beds near the outcrop. The desorbed gas could then migrate buoyantly updip to the outcrop and seep. The details of this potential process are not well understood at this time.

Heffern (1999), as quoted in the WYODAK Draft EIS (BLM, 1999c), compares the characteristics of the SJB of southwest Colorado and northwest New Mexico, with its coal fires, methane seeps, and high temperatures that have killed vegetation, with the PRB to evaluate the potential for coal fires and methane migration or seepage within the PRB. Although some similarities exist between the two basins, there are significant differences.

1. Basin pressurization and regional groundwater flow – the PRB is not an overpressured basin, as is the SJB. Groundwater flow in the PRB coal aquifer is downdip, toward the center of the basin (USGS, 1986b), rather than updip toward the outcrop.

2. Recharge from clinker - Unlike the SJB where there is little groundwater recharge or clinker at the coal outcrop, extensive deposits of porous clinker occurring in the PRB near the coal mines trap rainfall and snowmelt and recharge the coal aquifers (USGS, 1988; Peacock, 1997).

3. Coal characteristics - The bituminous coal in the SJB, while having less volatile matter, has developed better cleat and fractures than the sub-bituminous coal in the PRB. Due to its cleat, the SJB coal must be completely dewatered to achieve maximum production. The methane in the SJB is largely thermogenic, generated at depth from the high temperatures and pressures associated with burial. In the PRB, the methane is biogenic, and water is retained in the cell structure of the coal. In the PRB, overpumping of water from the coal could shut off methane flow if the cell structure collapses, rather than releasing methane (Selvig and Olde, 1953).

4. Basin structure - In the SJB outcrop area, where methane seepage occurs, it is confined to a much smaller area. Therefore, methane seepage may be more concentrated in the SJB than in the PRB. The SJB also is more highly deformed than the PRB and contains more faults and fractures that could serve as conduits for methane migration. Aubrey, et al. (1998) also notes the lack of substantial caprock in the SJB that would limit the flow of groundwater or methane migration.

5. Experience in existing mines - Mine fires are common in piles of coal fines and along the highwall in PRB mines, and are regularly extinguished. Since CBM development began, mine inspectors have not noted a significant increase or decrease in the number of fires in coal pits located east of the Marquiss and Lighthouse CBM projects where, to date, groundwater drawdown due to CBM development has been greatest. Moreover, the frequency of coal fires in these pits is similar to that for coal pits located some distance from CBM development.

Methane seepage can occur naturally in the vicinity of near-surface coal seams (Glass et al., 1987 and Jones et al., 1987). The potential for methane migration within the PRB is not limited to areas containing near-surface coal seams or areas where CBM drawdown has occurred. Methane migration potentially could occur at widespread locations within the PRB, as methane can migrate long distances along naturally occurring joints or fractures in rocks. Whether methane migration occurs in the PRB and whether methane seepage could accelerate the natural process of coal combustion is an unresolved question.

GROUNDWATER BALANCE

Groundwater resources can be balanced against current groundwater production and projected CBM water production within watersheds of the PRB. Exhibit 27 represents a calculated estimate of the water resources that exist in the coal seams of the Montana portion of the PRB. The estimate utilizes the acres within each watershed that have known coal occurrences that could be utilized for CBM development from Exhibit 3. Each acreage figure is multiplied by an average coal thickness of 70 feet from USGS Prof. Paper 1625-A. This is a volume figure that can be used with a porosity estimate (2%) to derive a total in-place groundwater volume for each watershed. These figures add up to an estimated 249.73 billion cu ft of groundwater for the projected CBM area of the PRB. This total does not include the volume of all the coal seams in the PRB, instead only those coals in the CBM potential development area. This total does not include waters held in non-coal aquifers.

EXHIBIT 27 - TOTAL GROUNDWATER RESOURCES IN THE COAL SEAMS OF THE MONTANA PRB WATERSHEDS

Calculated estimate of the water resources that exist in the coal seams of the Montana PRB

WATERSHED	COALBED THICKNESS (feet)	AVERAGE POROSITY OF THE COALS	TOTAL ACRES OF WATERSHED	TOTAL GROUNDWATER RESOURCE OF WATERSHED (Billion cu ft)
Little Big Horn	70	0.02	87,000	5
Little Powder	70	0.02	29,500	2
Lower Bighorn	70	0.02	121,500	7.5
Lower Tongue	70	0.02	1,374,000	84
Lower Yellowstone-Sunday	70	0.02	687,500	42
Middle Powder	70	0.02	368,500	22.5
Mizpah	70	0.02	24,000	1.5
Rosebud	70	0.02	81,4000	49.5
Upper Tongue	70	0.02	589,000	34
TOTAL			**4,095,000**	**248**

Exhibit 28 shows a calculation of the potential water production resulting from the maximum number of CBM wells (from the RFD) for each PRB watershed per year. The average water production rate was calculated from an exponential trend analysis and the details can be seen in Appendix A. The table illustrates that the watersheds with the greatest water production are those with the most wells, i.e. Lower Tongue River, Upper Tongue River and Rosebud. The total water production for all CBM wells in all the watersheds is 4.4 billion cu. ft. per year or approximately 1.75 percent of the water in the coal seems of the Montana PRB Watersheds.

EXHIBIT 28 - MAXIMUM POTENTIAL PRODUCED CBM WATER BY MONTANA PRB WATERSHEDS

Calculation of the potential water production resulting from the maximum number of CBM wells from the RFD full-field scenario for each PRB watershed per year.

WATERSHED	EFFECTIVE ACRES (Acres)	MAX POTENTIAL PRODUCING WELLS	AVERAGE WATER PRODUCTION RATE PER WELL (gpm)	MAX POTENTIAL PRODUCED CBM WATER PER YEAR (Billion cu ft)	MAX POTENTIAL PRODUCED CBM WATER PER YEAR IN GPM (cfs)
Little Big Horn	87,179	1,050	2.5	0.184	2620 (5.80)
Little Powder	29,605	278	2.5	0.049	697 (1.55)
Lower Bighorn	121,538	1,200	2.5	0.211	3000 (6.70)
Lower Tongue	1,374,159	5,183	2.5	0.910	12,950 (28.9)
Lower Yellowstone-Sunday	687,303	2,568	2.5	0.451	6400 (14.3)
Middle Powder	368,349	3,167	2.5	0.556	7,900 (17.5)
Mizpah	23,941	224	2.5	0.039	555 (1.25)
Rosebud	813951	5397	2.5	0.948	13,500 (30.0)
Upper Tongue	589009	5806	2.5	1.020	14,500 (32.3)
TOTAL	**4,095,034**	**24,873**	**2.5**	**4.4**	**62,600 (140)**

SURFACE WATER IMPACT FROM DISCHARGE

Impacts to surface water from discharge of CBM water can be severe depending upon the quality of the CBM water. Some watersheds may be able to absorb the discharged water while others are sensitive to large amounts of low-quality CBM water. Surface water quality in the watersheds is tabulated in Exhibit 29. Water quality data is from stream gauging points maintained by the USGS. These multi-year collections of water quality data illustrate changes within the stream from times of high run-off (typically June for the PRB) when the river is the highest and water is mostly the result of precipitation from spring rains and melting snow. During periods of high flow the streams and rivers contain higher quality water. The USGS data also contains data on base-flow conditions (typically winter in the PRB) when streams are at their lowest flow and water quality is the lowest since much of the water is recharge from alluvial and bedrock aquifers where groundwater is often of low quality. Water quality data consisting of stream flow and SAR is averaged for a number of USGS gauging points to give base-flow information as well as high-flow conditions. Some streams such as the Tongue River show strong contrast between high-flow and base-flow rates while Mizpah shows the high contrast in water quality (SAR) from base-flow to high-flow. In addition to surface water information, projected CBM water discharge data is also included for comparison; the quality of discharge water is estimated to be the same as produced water from the CX Ranch field, SAR = 47. It is likely however that some of the coal aquifers contain water that differs from the CX Ranch produced waters.

EXHIBIT 29 - SURFACE WATER QUALITY BY WATERSHEDS

Tabulation of surface water quality in the watersheds of the Montana portion of the PRB gathered from USGS stream gauging points.

WATERSHED	MAX CBM WATER DISCHARGE (From Exhibit 28)		AVERAGE BASE-FLOW		AVERAGE HIGH-FLOW	
	RATE	SAR	RATE	SAR	RATE	SAR
Little Big Horn (near Wyola)	5.8 cfs	47	61.8 cfs	1.2	526 cfs	0.2
Little Big Horn (near Crow Agency)			123 cfs	NA	782 cfs	NA
Little Big Horn (near Hardin)			138 cfs	2.0	851 cfs	0.5
Little Yellowstone-Sunday (Myers)	14.3 cfs	47	4200 cfs	1.7	42,000 cfs	0.7
Little Yellowstone-Sunday (Hysham)			0.01 cfs	8.5	280 cfs	1.5
Little Yellowstone-Sunday (Colstrip)			0.6 cfs	4.5	65 cfs	1.5
Little Powder (near Broadus)	1.55 cfs	47	0.35 cfs	NA	69	NA
Lower Bighorn (near St Xavier)	6.70 cfs	47	1750 cfs	2.5	10,300 cfs	1.7
Lower Bighorn (near Big Horn)			640 cfs	3.7	21,500 cfs	1.2
Mizpah (near Mizpah)	1.25 cfs	47	26 cfs	21.0	60.1 cfs	6.5
Middle Powder (near Moorhead)	17.5 cfs	47	153 cfs	5.2	1433 cfs	2.5
Middle Powder (near Broadus)			198 cfs	NA	1077 cfs	NA
Rosebud (at Reservation Boundary near Kirby)	30 cfs	47	1.78 cfs	0.8	15.7 cfs	0.6
Rosebud (near Colstrip)			7.5 cfs	1.5	56.5 cfs	1.1
Rosebud (at mouth near Rosebud)			9.02 cfs	3.7	77.0 cfs	1.6
Upper Tongue (at state line)	32.3 cfs	47	181	NA	1724 cfs	NA
Upper Tongue (at Tongue R. Dam near Decker)			175	1.1	1467 cfs	0.4
Lower Tongue (near Birney Day School)	28.9 cfs	47	185	1.4	1202 cfs	0.4
Lower Tongue (near Ashland)			206	NA	2073 cfs	NA
Lower Tongue (at Miles City)			194	2.4	1305 cfs	0.6
TOTAL	**115.75 cfs**	**47**				

Produced CBM water can have impacts on surface water if it is discharged directly to streams and rivers. In a highest impact scenario, all the water produced in the projected CBM wells would be discharged to the primary drainage in each watershed. The results of this scenario are tabulated in Exhibit 30. In this table, the CBM discharge rate and base flow are taken for each watershed (from Exhibit 28) and added together to give the resultant combined flow. If the worst-case scenario would develop – 100% of the CBM produced water would be discharged at the gauging point during the average base-flow conditions. The resultant SAR values are a weighted average of the maximum CBM discharge and the average base-flow. Again for this scenario water quality was assumed to match that of CX Ranch. The biggest impacts would be those streams with low flow volumes and low SAR values such as Rosebud (near Kirby) that have a substantial increase in flow from the CBM discharge waters. In the case of Rosebud (near Kirby) the SAR increases from 0.8 to 44.4 and has an increase in flow from 1.78 cfs to 31.78 cfs.

EXHIBIT 30 - WORST-CASE DISCHARGE SCENARIO – BY WATERSHED – USING CX RANCH WATER QUALITY

Highest impact scenario for Montana PRB as tabulated from CX Ranch quality water for primary drainage in each watershed.

WATERSHED	MAX CBM WATER DISCHARGE		AVERAGE BASE-FLOW		RESULTANT FLOW: DISCHARGE + BASE-FLOW	
	RATE	SAR	RATE	SAR	TOTAL VOLUME	SAR
Little Big Horn (Near Wyola)	5.8 cfs	47	61.8 cfs	1.2	67.6 cfs	5.1
Little Big Horn (near Crow Agency)			123 cfs	NA	128.8 cfs	NA
Little Big Horn (near Hardin)			138 cfs	2.0	144.8 cfs	3.8
Little Yellowstone-Sunday (Myers)	14.3	47	4200 cfs	1.7	4214.3 cfs	1.9
Little Yellowstone-Sunday (Hysham)			0.01 cfs	8.5	14.31 cfs	47
Little Yellowstone-Sunday (Colstrip)			0.6 cfs	4.5	14.9 cfs	45
Little Powder (near Broadus)	1.55 cfs	47	0.35 cfs	NA	1.90 cfs	NA
Lower Bighorn (near St Xavier)	6.70 cfs	47	1750 cfs	2.5	1756.7 cfs	2.7
Lower Bighorn (near Big Horn)			640 cfs	3.7	646.7 cfs	4.1
Mizpah (near Mizpah)	1.25 cfs	47	26 cfs	21.0	28.25 cfs	21.4
Middle Powder (near Moorhead)	17.5 cfs	47	153 cfs	5.2	179.5 cfs	6.1
Middle Powder (near Broadus)			198 cfs	NA	224.5 cfs	NA
Rosebud (at Reservation Boundary near Kirby)	30 cfs	47	1.78 cfs	0.8	31.78 cfs	44.4
Rosebud (near Colstrip)			7.5 cfs	1.5	37.5 cfs	37.9
Rosebud (at mouth near Rosebud)			9.02 cfs	3.7	39.02 cfs	37
Upper Tongue (at state line)	32.3 cfs	47	181 cfs	NA	213.3 cfs	NA
Upper Tongue (at Tongue R. Dam near Decker)			175 cfs	1.1	207.3 cfs	8.25
Lower Tongue (near Birney Day School)	28.9 cfs	47	185 cfs	1.4	213.9 cfs	7.6
Lower Tongue (near Ashland)			206 cfs	NA	234.9 cfs	NA
Lower Tongue (at Miles City)			194 cfs	2.4	222.9 cfs	7.1

Except for the Little Big Horn and the Mizpah watersheds, the worst-case discharge would have unacceptable impacts on stream conditions. For both the Little Big Horn and Mizpah, the number of wells is expected to be so small, that discharge volumes are also expected to be small and dilution will be sufficient to avoid any significant degradation to water in terms of SAR. Other streams and rivers cannot withstand the maximum discharge of CBM water; the calculated resultant water would be unusable for irrigation. This statement is based upon the maximum number of CBM wells as computed by the RFD and the potential CBM map as well as the assumption that produced water will be the same quality as CX Ranch water. If CBM produced water is less sodic than the CX Ranch water and closer to river water in quality, watersheds will be able to accept more CBM discharge. As discharge waters increase in volume, however, there is the potential to impact riparian areas via increased erosion and sediment transport. Exhibit 31 casts watershed flow rates against worst-case discharge rates at each potential discharge point. Increases caused by discharge range from approximately 0.1% if all 5,183 CBM wells discharge into the Lower Tongue near Ashland, MT up to 191% if all 1250 CBM wells discharge into the Rosebud near Kirby, MT. For the former, little erosion would be expected while for the latter, significant impact could be expected if riparian areas were prone to erosion.

EXHIBIT 31 - DISCHARGE VOLUMES AND HIGH-FLOW VOLUMES BY WATERSHEDS
Comparison of watershed flow rates to worst-case discharge rates at each potential discharge point.

WATERSHED	MAXIMUM CBM WATER DISCHARGE RATE	AVERAGE HIGH-FLOW RATE
Little Big Horn (Near Wyola)	5.8 cfs	526 cfs
Little Big Horn (near Crow Agency)		782 cfs
Little Big Horn (near Hardin)		851 cfs
Mizpah (near Mizpah)	1.25 cfs	60.1 cfs
Middle Powder (near Moorhead)	17.5 cfs	1433 cfs
Middle Powder (near Broadus)		1077 cfs
Rosebud (at Reservation Boundary near Kirby)	30 cfs	15.7 cfs
Rosebud (near Colstrip)		56.5 cfs
Rosebud (at mouth near Rosebud)		77.0 cfs
Upper Tongue (at state line)	32.3 cfs	1724 cfs
Upper Tongue (at Tongue R. Dam near Decker)		1467 cfs
Lower Tongue (near Birney Day School)	28.9 cfs	1202 cfs
Lower Tongue (near Ashland)		2073 cfs
Lower Tongue (at Miles City)		1305 cfs